



Land-use modelling by cellular automata

Hansen, Henning Sten

Published in:
NORDGI : Nordic Geographic Information

Publication date:
2006

Document Version
Publisher's PDF, also known as Version of record

[Link to publication from Aalborg University](#)

Citation for published version (APA):
Hansen, H. S. (2006). Land-use modelling by cellular automata. In P. Takala (Ed.), *NORDGI : Nordic Geographic Information: proceedings from the Nordic GIS Conference, Helsinki 2006* (pp. 72-74). National Land Survey of Finland. <http://www.ginorden.org/Members/karstenl/nyheter/the-18th-nordic-gis-conference-in-helsinki-2-4-october-2006/>

General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal -

Take down policy

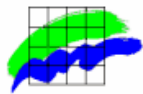
If you believe that this document breaches copyright please contact us at vbn@aub.aau.dk providing details, and we will remove access to the work immediately and investigate your claim.

Nordic GIS Conference

Helsinki, 2. – 4. October 2006

Land-use Modelling by Cellular Automata

Henning Sten Hansen



Ministry of Environment
National Environmental Research Institute

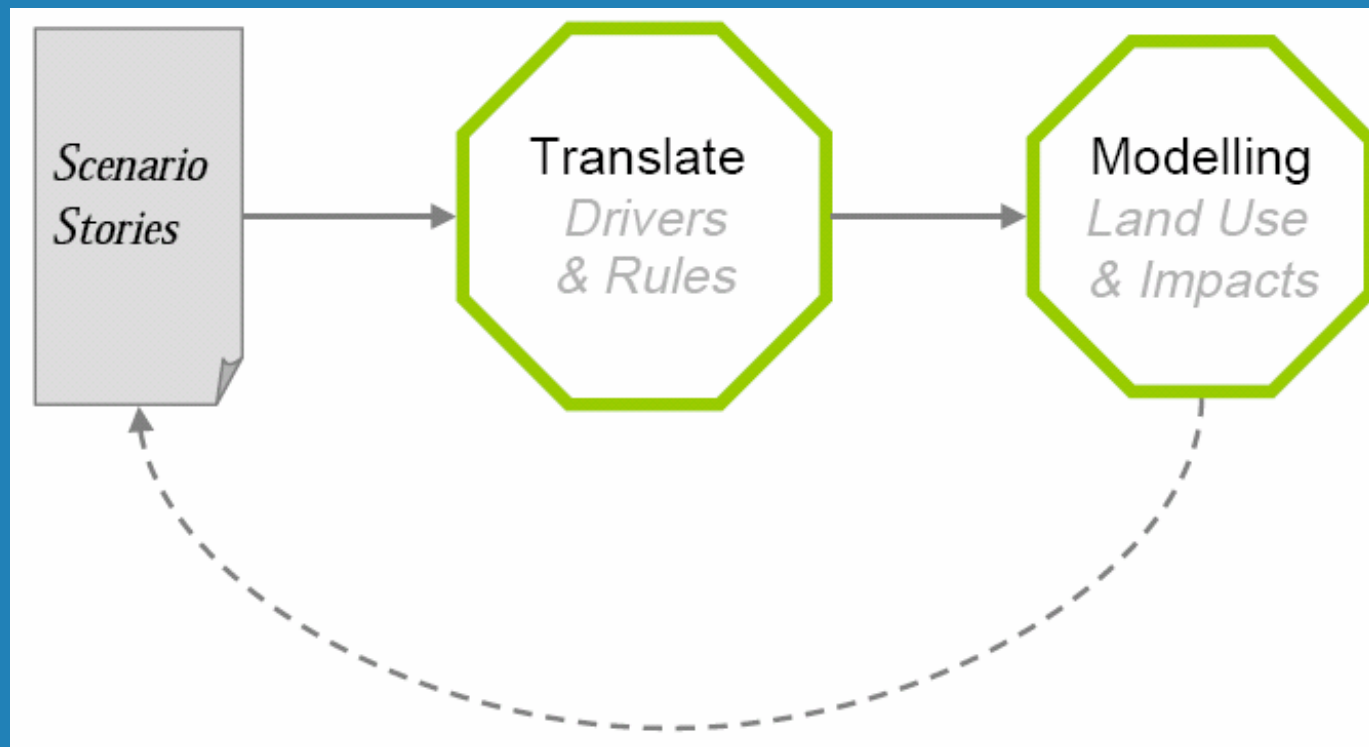
A fragment of a topographic map is visible on the left side of the slide. It shows contour lines, a road, and some buildings. Labels like 'Knäggåsa' and 'Örsemose' are partially visible.

Overview

- The principles of cellular automata
- Previous CA based land-use studies
- The current model
- Conclusions and further work



From words to models



A vertical strip on the left side of the slide shows a portion of a topographic map. It features contour lines, a network of roads, and some place names. The name 'Knäuper' is visible at the top, and 'Örsemose' is visible further down. The map is rendered in white lines on a dark blue background.

Cellular Automata - CA

- Introduced in the late fourties abyf John von Neumann and Stanislaw Ulam
- In the late sixties John Horton Conway developed *The Game of Life*
- CA is discrete dynamical systems and is often described as a counter part to partiel differential equations for continuous systems



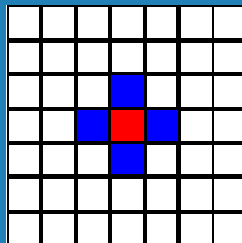
Cellular Automata

The most important properties of a CA system

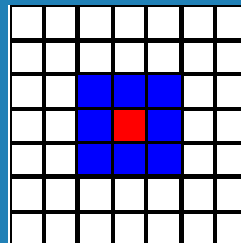
- A regular n-dimensional grid (n is often equal to 1 or 2), where every cell within the system has a discrete state
- A dynamic behaviour, defined by rules describing the state of a cell at the subsequent time on the basis of the state of the neighbouring cells

Local interaction leads to global dynamics

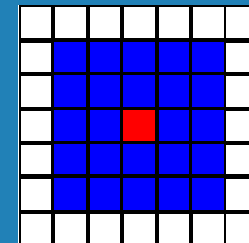
The main principle in CA



von Neumann
Neighbourhood



Moore
Neighbourhood



Udvidet
Moore Neighbourhood



General principles for CA

$S_{ij}(t)$ the state for the cell x_{ij} at the time t

$S_{ij}(t+1)$ the state for the cell x_{ij} at the time $(t + 1)$

$$S_{ij}(t+1) = F(S_{\Omega(i,j)}(t))$$

where Ω_{ij} represents the neighbouring cells to the cell x_{ij}



IF

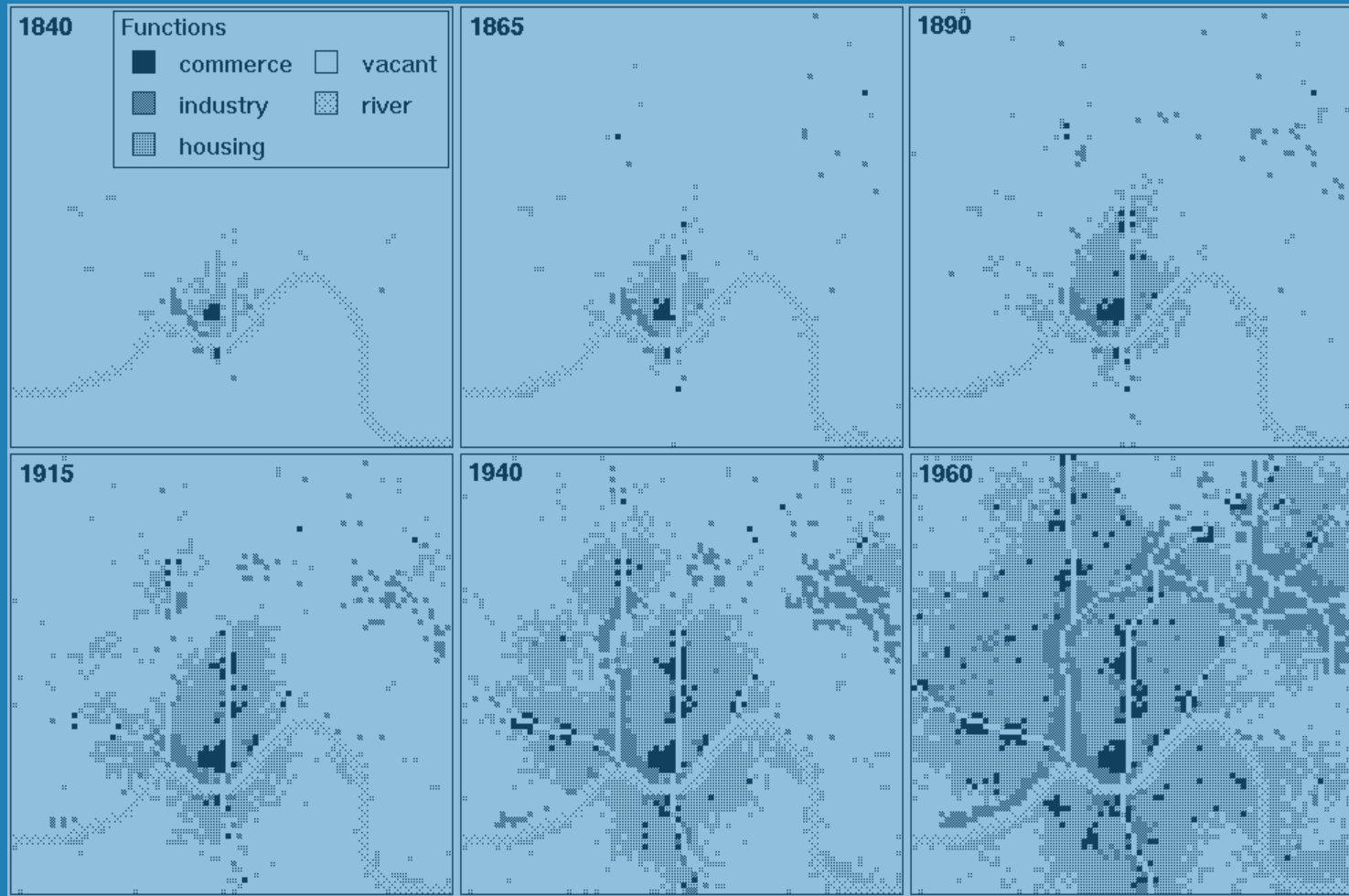
(something happens among the neighbours of the cell)

THEN

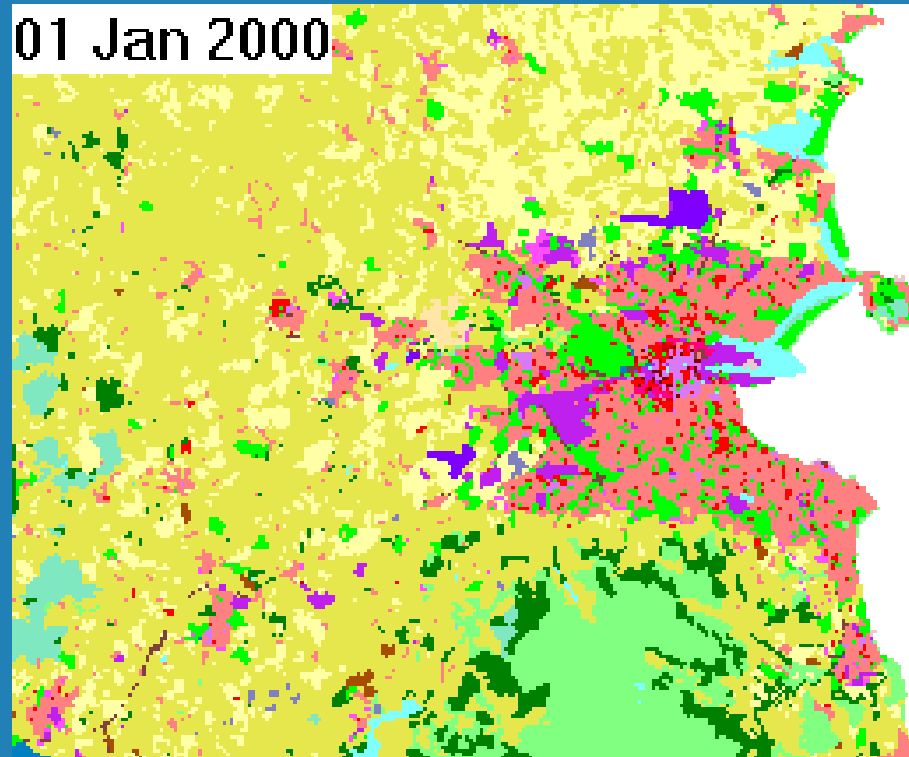
(the cell will change its state at the next time step)



Cincinnati's development 1840 - 1960



Simulating Dublin's development

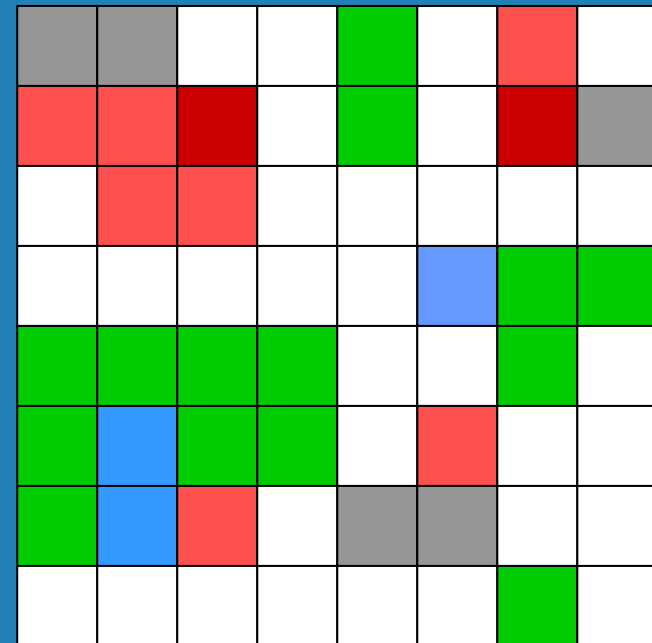


The Moland Project)



CA model for land-use dynamics

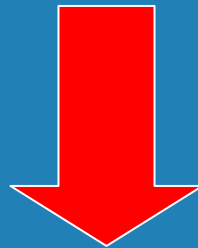
- The *States* represents the various land-use classes
 - Dynamic states
 - Passive states
 - Static features



The Model

Land-use
Accessibility
Suitability
Zones and plans
Socio-economic data

Input



Cellular Automata
Based model

Scenarios :
Future
Land-use



Indicators

Sustainability
? ? ?



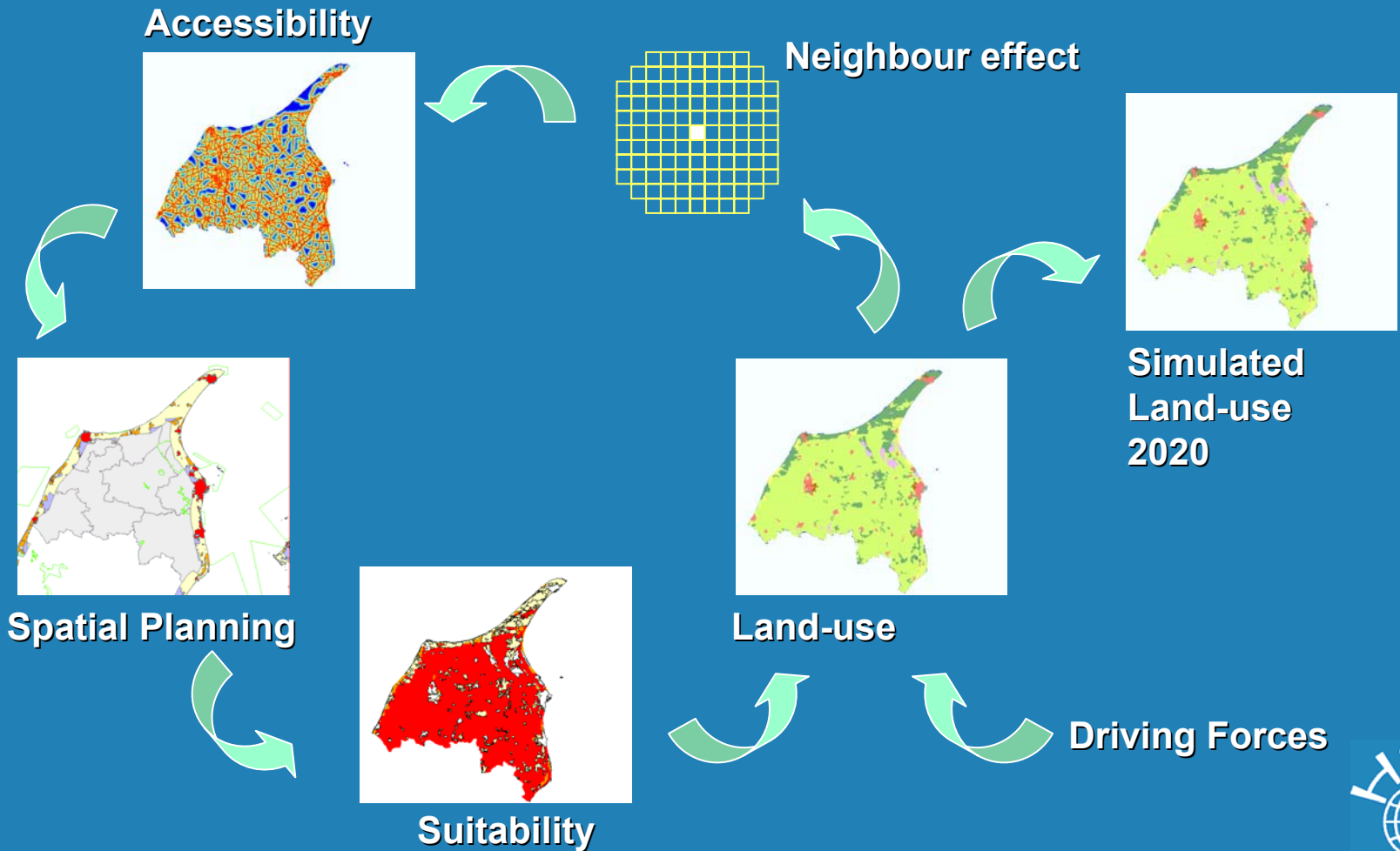
A fragment of a topographic map is visible on the left side of the slide. It shows contour lines, a network of roads, and some place names. The names 'Knäuperhus' and 'Örsemose' are clearly legible. The map is oriented vertically, with the top of the fragment at the top of the slide.

Driving forces

- Spatial planning (environmental legislation, energy policy)
- Demography (population development, migration)
- Values of the society (quality of life, concern about the environment)
- Economic development
- Technological development (information society)
- Environmental impacts (emissions, climate changes)



The Model Concept



Calculation the *Neighbourhood effect*

$$R_{K,x,y}^t = \sum_c \sum_l w_{K,L,c} I_{c,l}$$

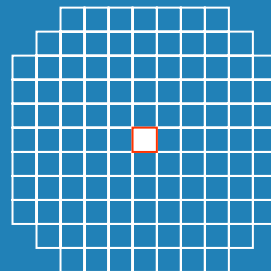
$$R_{Arealanv,x,y}^t = \sum FocalSum(Arealanv == n, Weight, Kernel)$$

$$R_L1(x,y) = FocalSum(LU == 1, WEIGHT, Kernel_L1L1) + \\ FocalSum(LU == 2, WEIGHT, Kernel_L1L2) \dots$$

$$R_L2(x,y) = FocalSum(LU == 1, WEIGHT, Kernel_L2L1) + \\ FocalSum(LU == 2, WEIGHT, Kernel_L2L2)$$

.....

Etc.



Accessibility

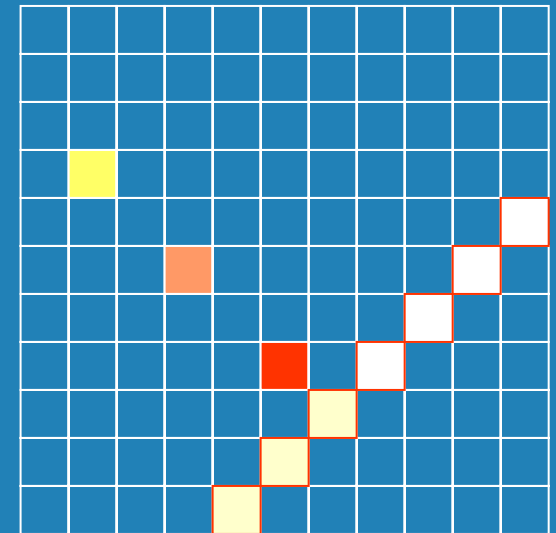
$$A_{K,x,y}^t = \frac{1}{1 + \frac{D}{a_K}}$$

■ $A = 1/(1 + \sqrt{2}) = 0,1239$

■ $A = 1/(1 + 3\sqrt{2}) = 0,1907$

■ $A = 1/(1 + 5\sqrt{2}) = 0,4142$

■ Transport network



A vertical strip on the left side of the slide shows a portion of a historical map. It features various symbols for land use, including fields, forests, and buildings. Text labels like 'Knäggåsa' and 'Örsemose' are visible in a cursive script.

How to make the CA model

- Decide about the active states, the passive states and the static features
- Decide the spatial resolution of the model
- Obtain minimum 2 land-use maps to do the calibration against the historical development (minimum 10 years between)
- Prepare the land-use data
- Define the distance-decay functions
- Run the model repeatedly and evaluate the effects of the changed rules

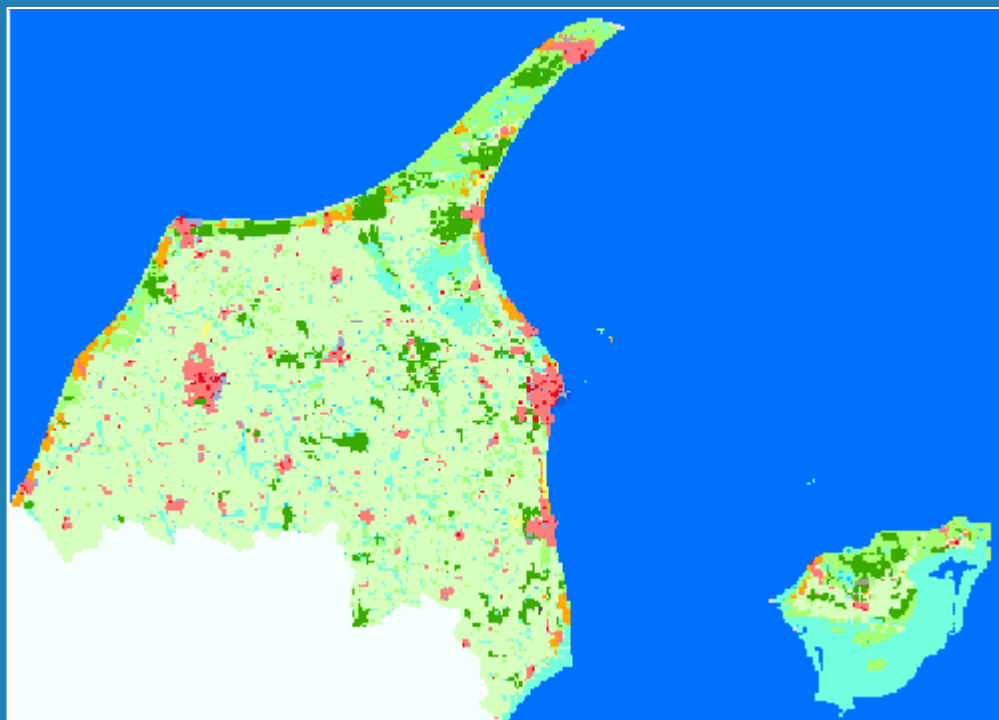


Land-use 1990

**CORINE
1990**

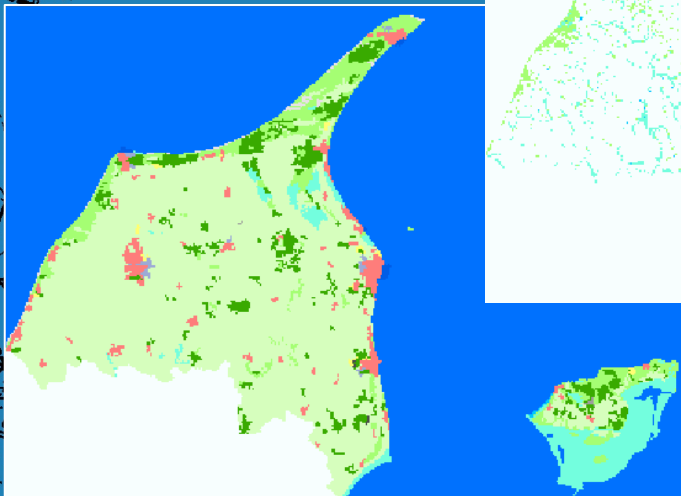
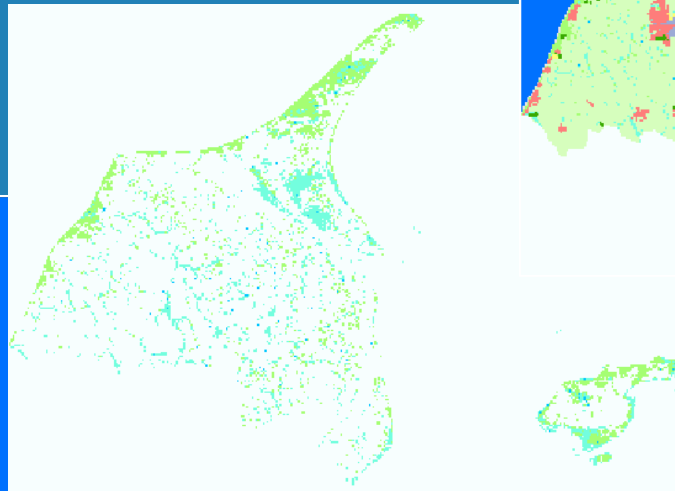
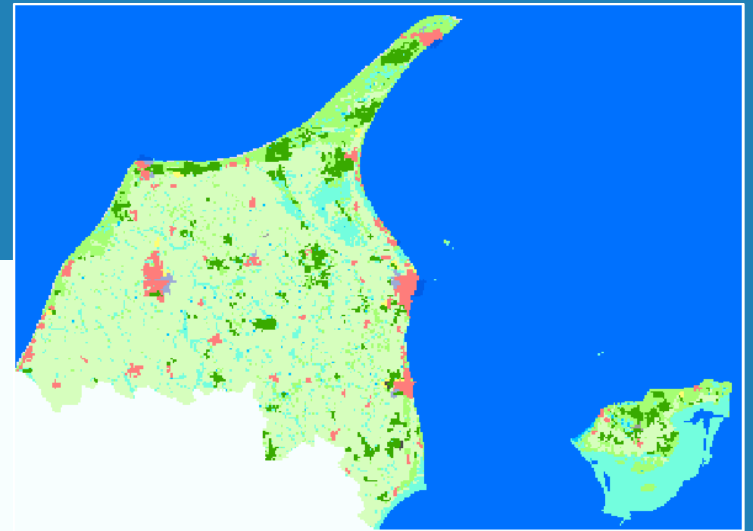
BBR

**Protected
Nature**



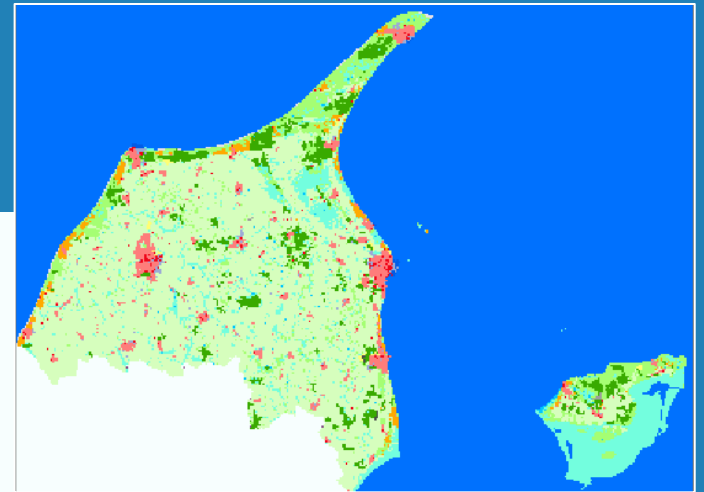
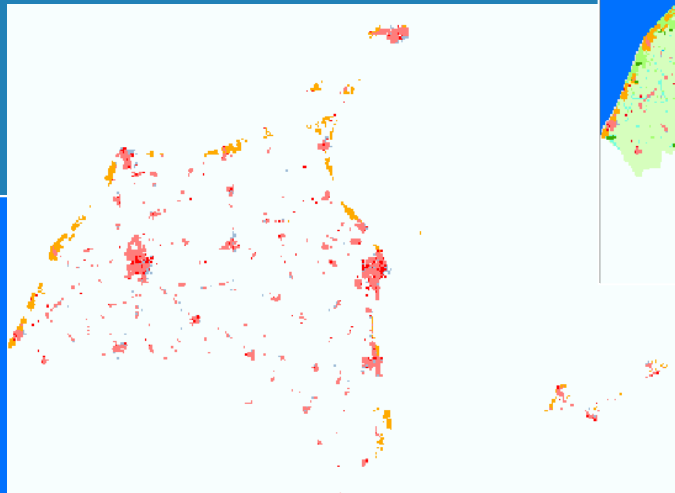
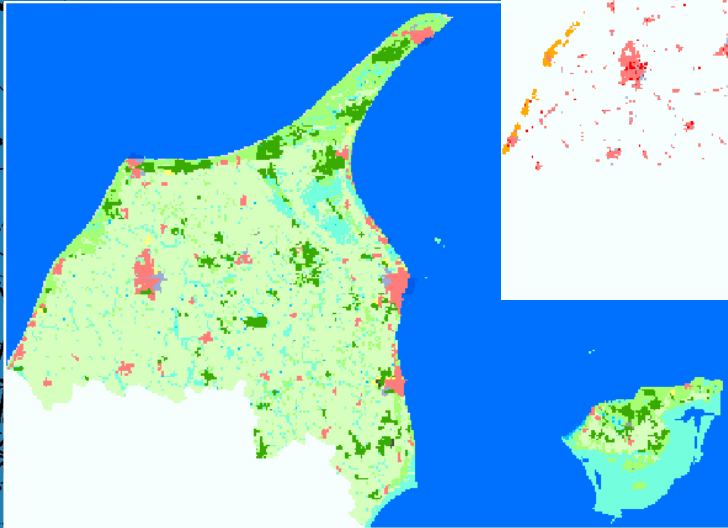
Add Protected Areas

Con(ProtectedAreas > 0, ProtectedAreas, Corine)

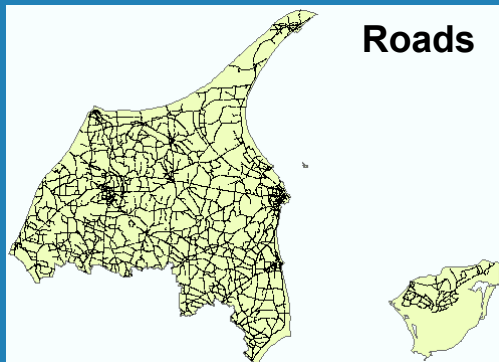


Add urban land-use

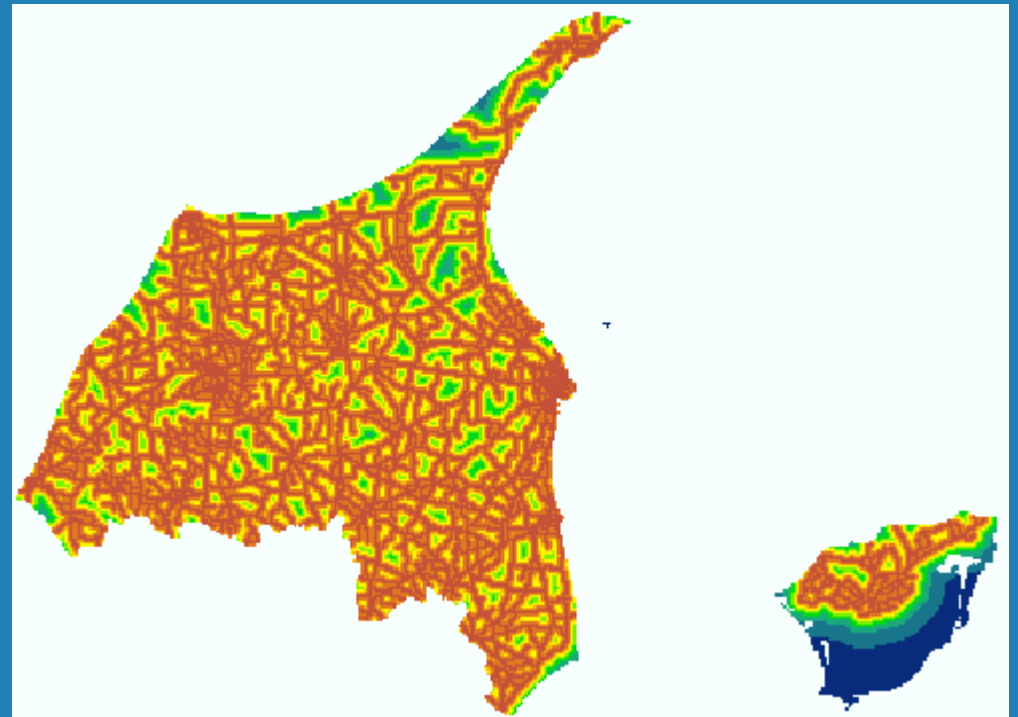
Con([UrbanLanduse] > 0, [UrbanLanduse], [CorinePlus])



Accessibility



$$A_{K,x,y}^t = \frac{1}{1 + \frac{D}{a_K}}$$

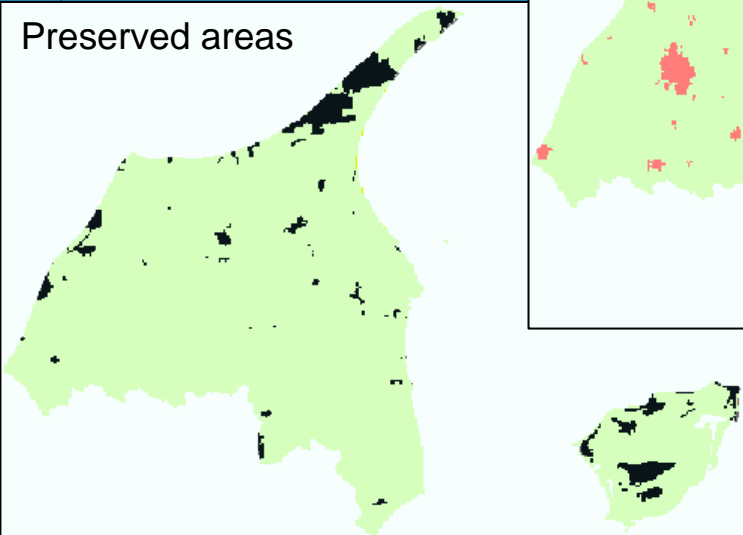


High

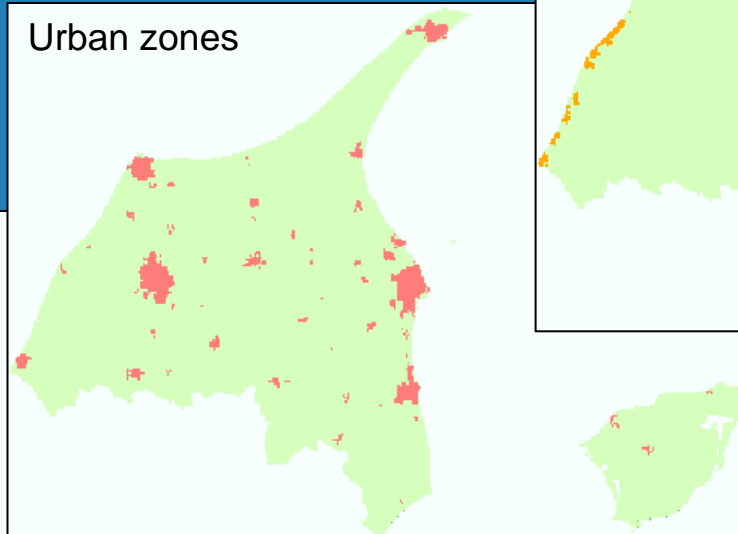
Low

Spatial Planning Zones

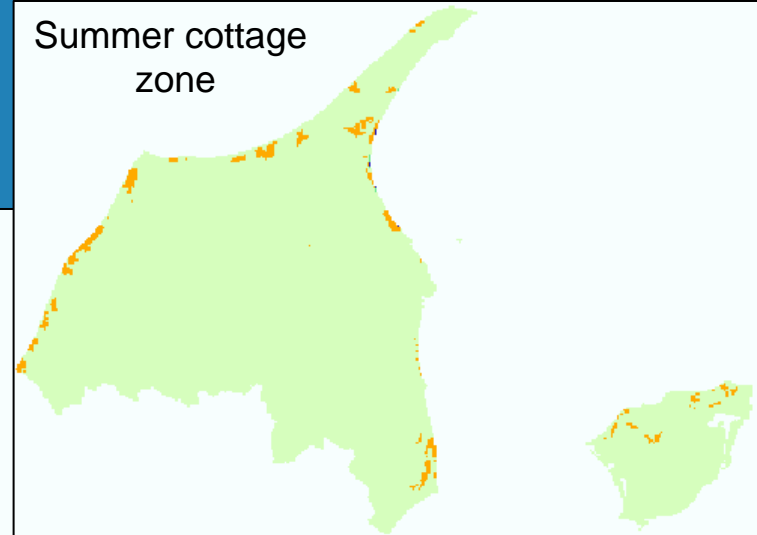
Preserved areas



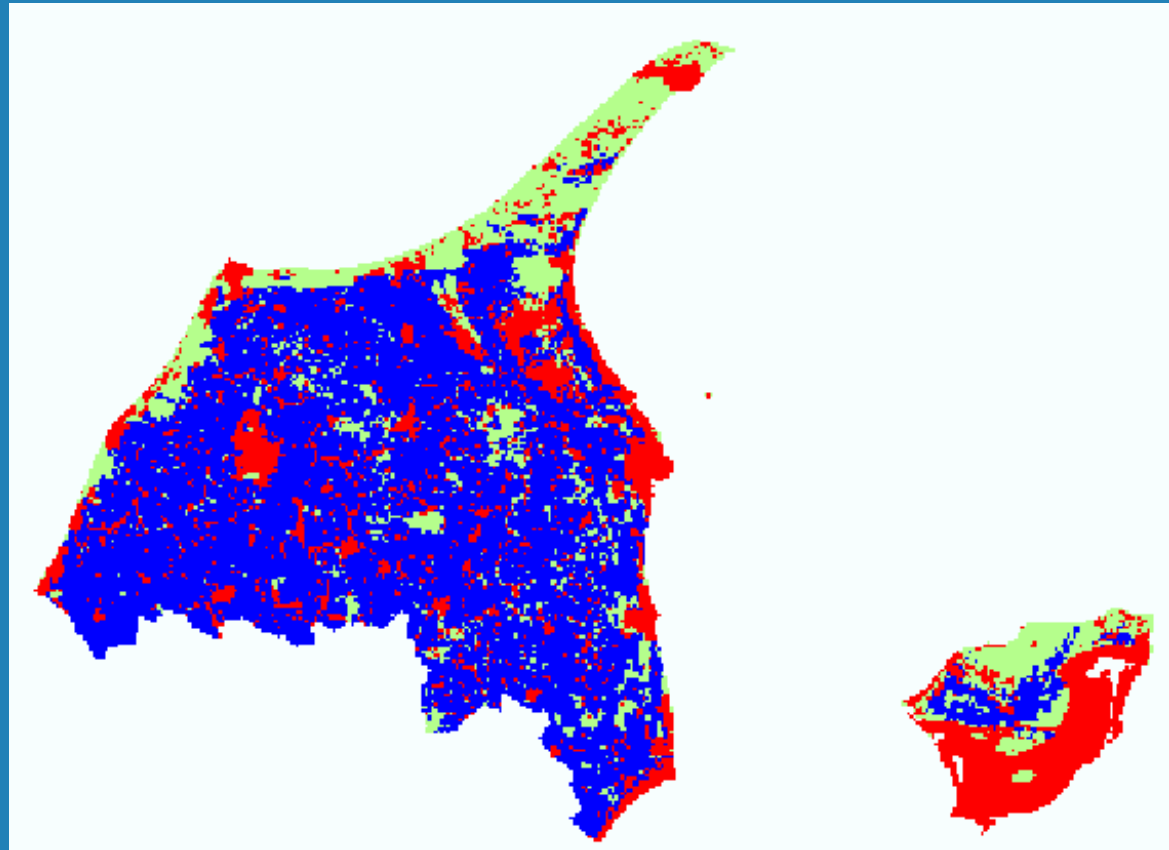
Urban zones



Summer cottage zone

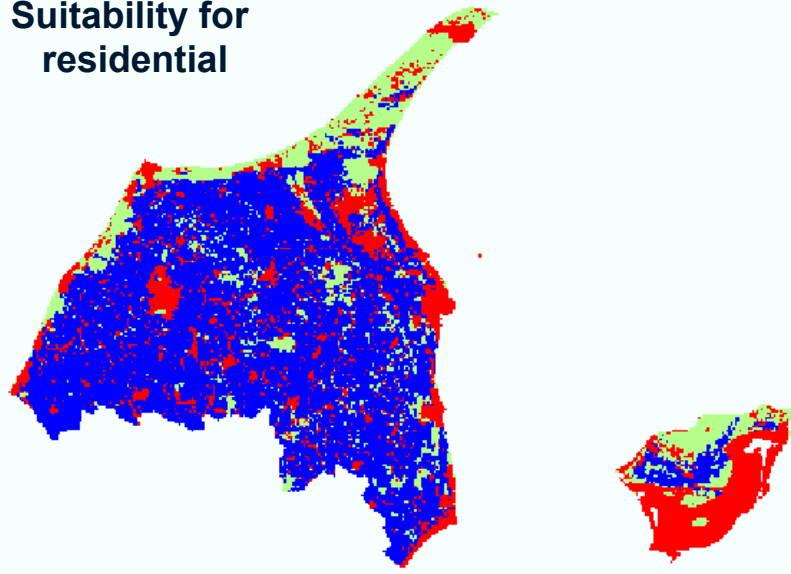


Suitability



Suitability

**Suitability for
residential**



- Suitability is based on
 - Existing land-use
 - Soil type
 - Terrain
 - More can be added !

A fragment of a topographic map is visible on the left side of the slide. It shows contour lines, a road, and some buildings. Labels like 'Knäuperus' and 'Örsemose' are visible.

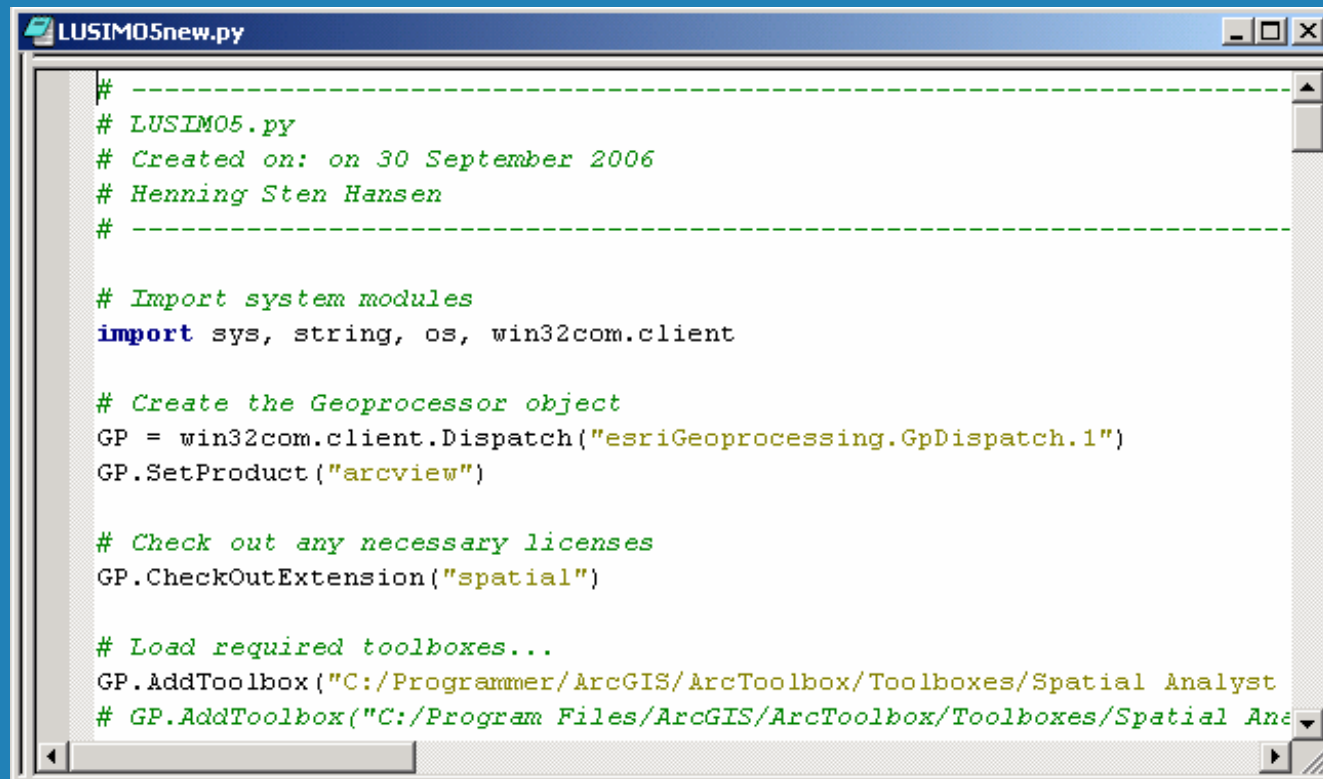
The Potential

- Suitability, accessibility, and zoning status are calculated for each of the active land-use classes
- Like in MURBANDY and MOLAND we calculate transition potentials for each cell from a set of suitabilities, accessibilities, zoning status and the neighbourhood effect
- The state for which a cell has the highest potential will be allocated to that cell
- However, there is the constraint that the number of cells in each state must be equal to the number demanded in that iteration



Implementation strategy

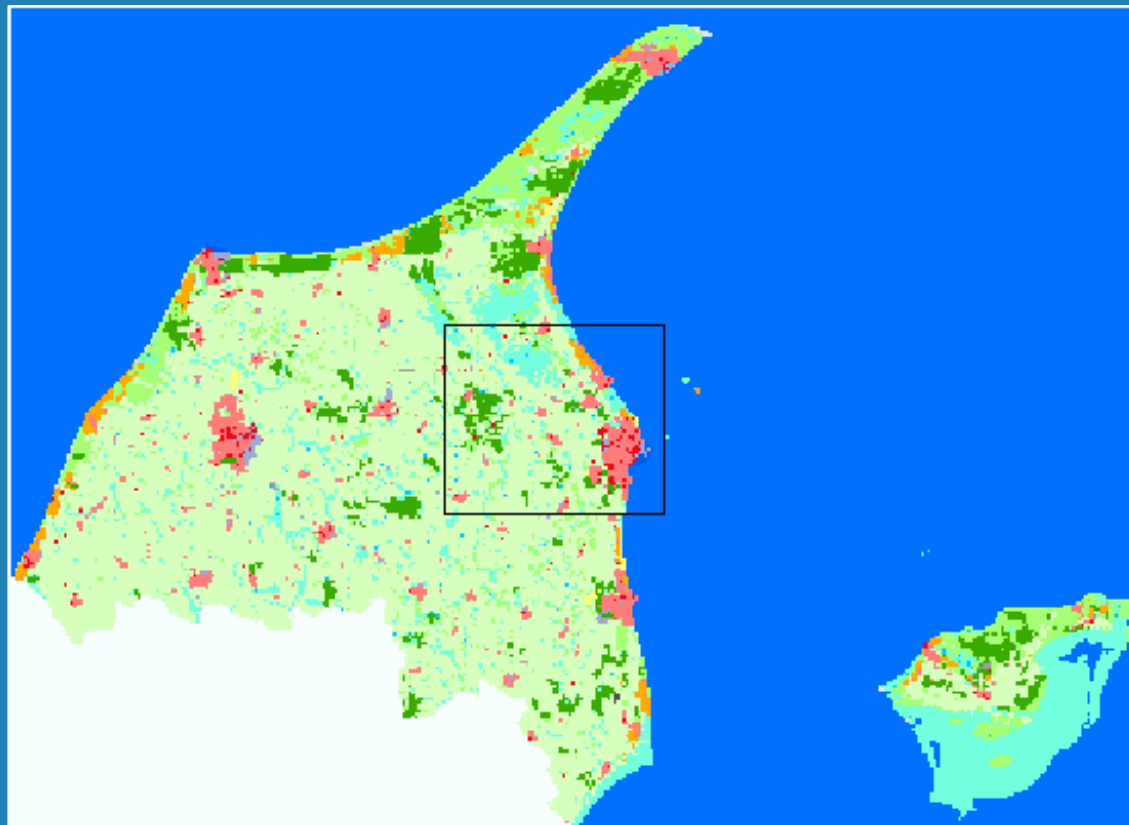
- Developed within the ArcGIS framework
- Programming language is Python



```
# -----  
# LUSIM05.py  
# Created on: on 30 September 2006  
# Henning Sten Hansen  
# -----  
  
# Import system modules  
import sys, string, os, win32com.client  
  
# Create the Geoprocessor object  
GP = win32com.client.Dispatch("esriGeoprocessing.GpDispatch.1")  
GP.SetProduct("arcview")  
  
# Check out any necessary licenses  
GP.CheckOutExtension("spatial")  
  
# Load required toolboxes...  
GP.AddToolbox("C:/Programmer/ArcGIS/ArcToolbox/Toolboxes/Spatial Analyst  
# GP.AddToolbox("C:/Program Files/ArcGIS/ArcToolbox/Toolboxes/Spatial Analyst
```

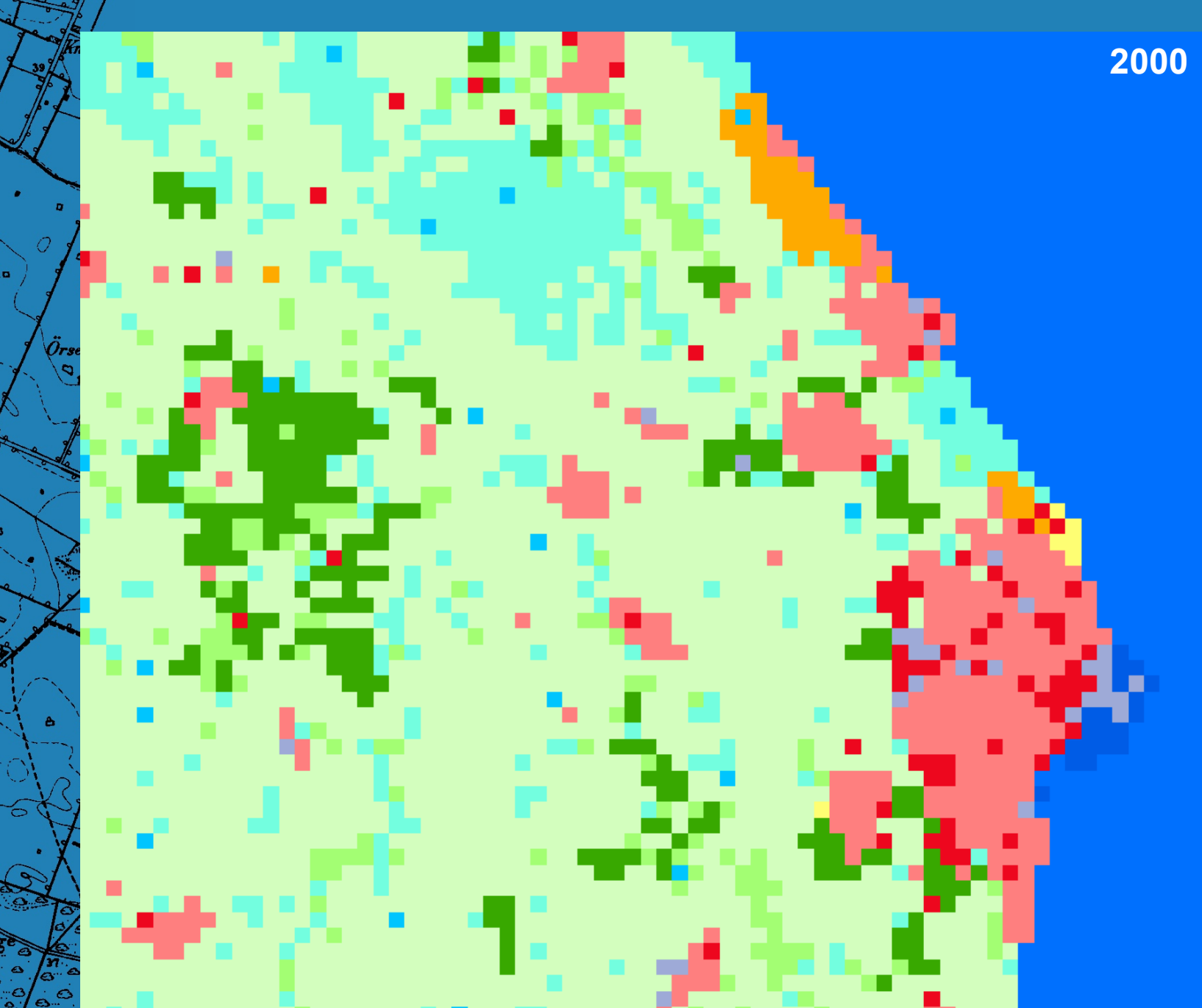


Land-use simulation 1990 - 2000

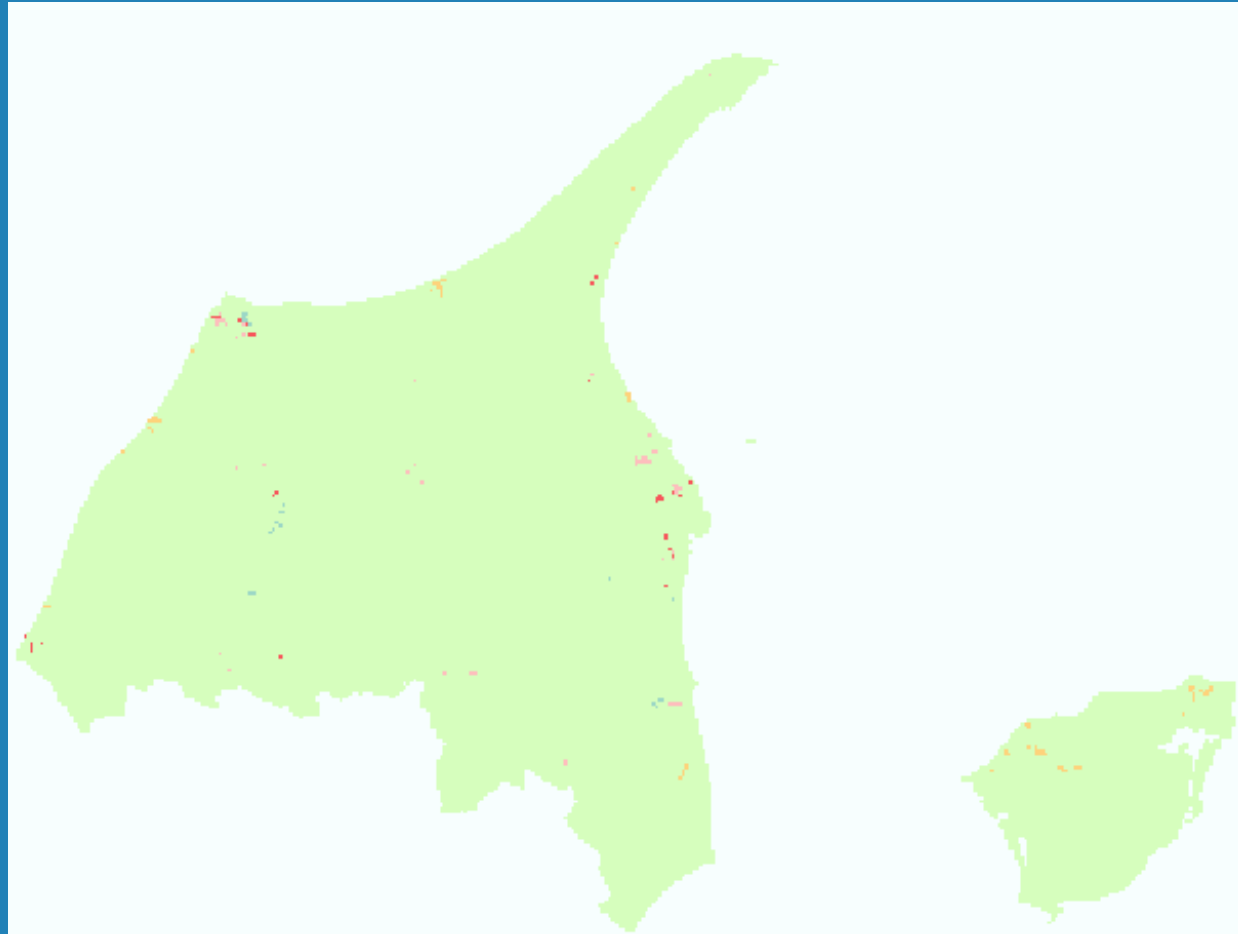


- Residential
- Summer cottages
- Industry
- Trade/service
- Ports
- Airports
- Deposits / mines
- Leisure
- Agriculture
- Forest
- Semi nature
- Dunes / heath
- Wetland
- Lake
- Sea

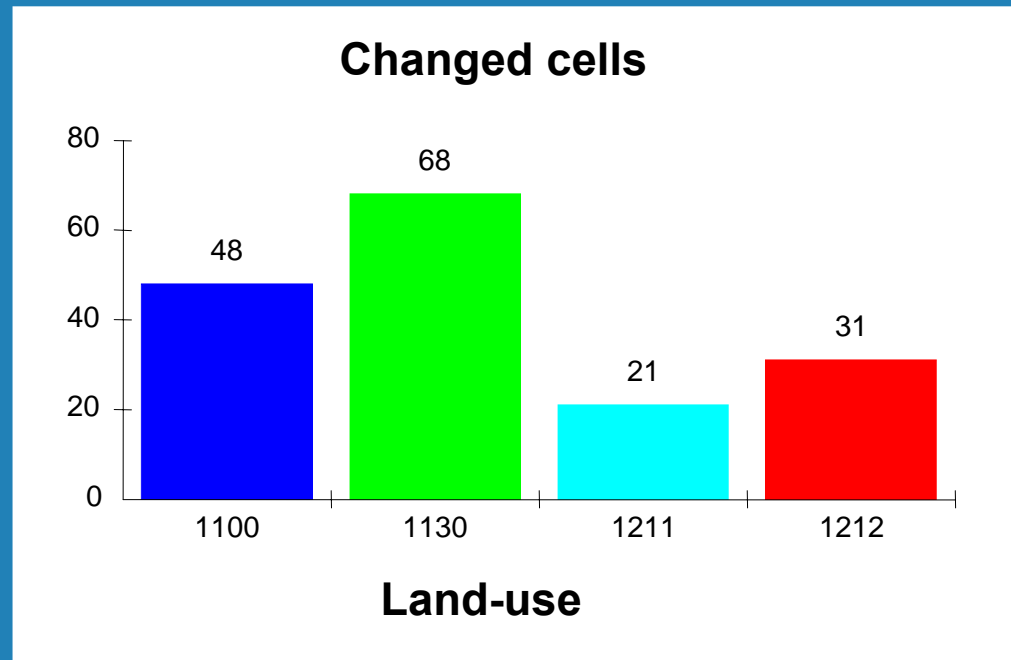
2000



Changed cells (1990 – 2000)



Changed cells



A vertical strip on the left side of the slide shows a portion of a topographic map. It features contour lines, a network of roads, and some place names in German, including 'Knäuperhau' at the top and 'Örsemose' further down.

Concluding remarks

- The current model is our first attempt to develop a flexible and easy to use CA based land-use simulation model
- Pro
 - Easy to run various scenarios for different spatial planning efforts
 - Easy to change the number of land-use categories
- Cons
 - Time consuming to estimate the distance decay functions between various land-use categories
 - Difficult to calibrate the model against historical data due to uncertainties in as well the start year as the end year for the calibration period





Further research

- Develop more effective calculation procedures to reduce the calculation time
- Improve the calibration procedure
- Use the model in a practical Coastal Zone Management Project – Forum Skagerrak.

THANK YOU FOR YOUR ATTENTION !!!

